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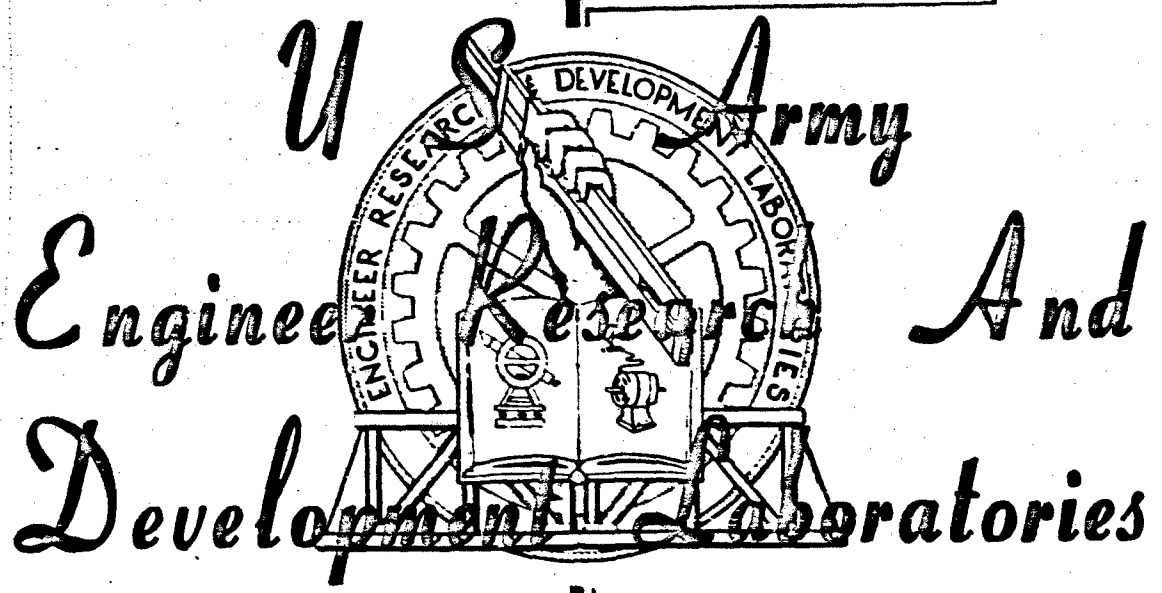
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USE OF POLARIZATION LIGHT FILTERS IN
AERIAL PHOTOGRAPHIC SEA SURVEYS

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USE OF POLARIZATION LIGHT FILTERS

IN AERIAL PHOTOGRAPHIC SEA SURVEYS

by

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USE OF POLARIZATION LIGHT FILTERS

IN AERIAL PHOTOGRAPHIC SEA SURVEYS

Aerial photographic surveys of the sea are frequently performed at the present time. The bottom of shallow portions of the sea is photographed to determine its depth, interpretation of underwater objects, mapping, and geological investigations [5, 7, 8, 9, 16]. Aerial photographic surveys of the surface of the sea are being performed to investigate sea waves and to map currents [1, 2, 4, 12, 13]. For these reasons, the struggle against errors occuring in aerial photographic surveys of seas and oceans assumes considerable importance. Among such serious errors is the image of the "sun spots", that is, the mirror reflection, on the aerial photographic film, of the sun light striking the surface of the water, and the sharp increase in light dissipation within the objective of the aerial camera, resulting from the intense brightness of the sun spot; this results in an excess of light on the portion of the aerial photograph that is opposite the spot image.

Figure 1 shows an aerial photograph of sea waves, ruined by the spots and internal light penetration.

This article presents the theory and methodology for reduction of these errors with the aid of polarized light filters (polaroids).

The idea of using polaroids in the struggle against sun spots on aerial photographs is not new. Specifically, mention is made of the desirability of the use of polaroids in French works [17, 18], dealing with aerial photographic surveys of sea and ocean waves. However, we know of neither theoretical nor experimental investigations of this problem.

For this reason, an experimental aerial photographic survey of the sea, utilizing polaroids, was performed by the Aeromethods Laboratory of the USSR Academy of Sciences in the summer of 1958. Figure 2a shows a photograph of shallow water. In
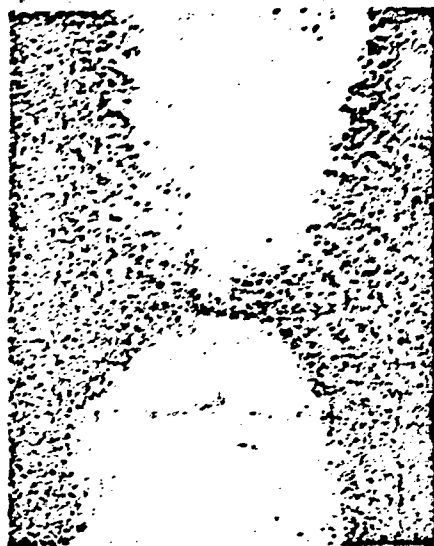
Fig. 1

it one can discern a sloping swell, the contours of muddied water in the center and and the bottom of the frame, as well as the bottom contour. The survey was performed with the aid of a polarization light filter in a cloudless sky. Shown in Figure 2b is the same area, photographed seven minutes after that in Figure 2a, but without a polaroid. The hot spot, caused by light diffusion in the objective, is clearly visible.

Figure 2 shows that during these experimental aerial photographic surveys it was possible to eliminate the sun spots. Consequently, the polaroid can actually be used in the struggle against hot spots and the resulting increased escape of light. However, it is obvious from the elementary theoretical considerations that polaroids cannot be looked upon as the universal means for counteracting hot spots. Thus, to determine when and how they are to be used, one must examine the theory of the problem.

Fig. 2a

Fig. 2b

1. The theory of diminution of brightness of the hot spot through use of the polaroid. It is known (for example, see[15]) that sunlight, reflected by the surface of the water, is partially polar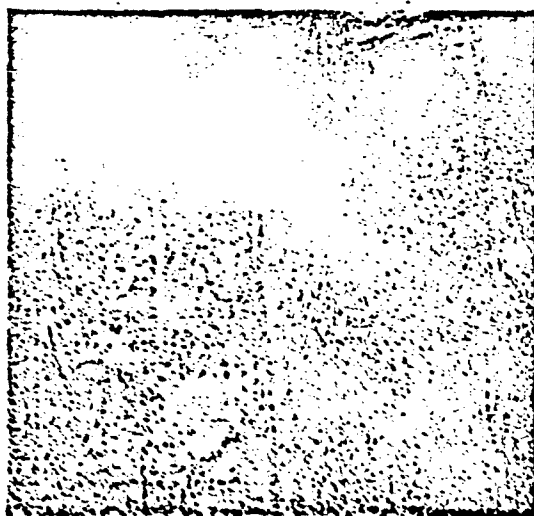ized in the brightness-decrease-reflection plane. The degree of polarization depends on the angle of incidence, and it approaches unity when that angle equals 53 (Brewster angle) and decreases to zero when the angle of incidence approaches 0° or 90°.

The ideal polaroid, when struck by partially polarized light, passes [3, 11] one-half of the natural light and a portion of the polarized light

$$T = 0.5(1 - q) + q \cos^2 \xi \tag{1}$$

Here, q is the degree of polarization of the light striking the polaroid;
  ξ is the angle between the directions of the light vector in the polarized ray passing through the thickness of the polaroid;
  T is that portion of light which passes through the ideal polaroid.
The real polaroid passes only a smaller portion of the light,

$$T_r = k[0.5(1 - q) + q \cos^2 \xi]. \tag{2}$$

Here, k is the coefficient which depends on the quality of the polaroid which equals approximately 0.7 - 0.8.

Formula (2) determines the portion of spot intensity passed by the polaroid. However, the polaroid decreases not only the brightness of the spot, but also the brightness of the object surveyed. It is necessary to replace this loss by increasing the power of the objective or the exposure by 2 : k times (the magnitude of 2 : k was confirmed experimentally). Thus, given a fixed exposure of the objects of the survey, use of the polaroid will reduce exposure of the spot to:

$$s = T_r : 0.5 \, k = 1 + q + 2 \, q \cos^2 \xi. \tag{3}$$

To proceed further, one must know the dependence of coefficient s on the conditions of the survey and the coordinates of the spotting point of the photograph.

It appeared that s can be represented as a function of three arguments: altitude of the sun, h, angular distance β of the particular point on the photograph from its center (inclination of the projecting ray), and angle ϑ between the radius vector of the point under examination and the radius vector opposite the sun's azimuth. These magnitudes can be considered as known, since azimuth and altitude of the sun can be taken from the tables [10] based on time of flight and coordinates of the area under survey; ϑ is measured directly on the aerial photograph when the azimuths of the sun and the flight are known; tg β is proportional to distance r of the point from the center of the photograph

$$\text{tg } \beta = r : f, \tag{4}$$

where f is the focal distance of the aerial camera.

With the aid of the Frenel [15] formulas, we express q, the degree of polarization, through angle of incidence φ formed by the sun's rays with the surface of the water and the corresponding refraction angle ψ

$$q = \left[\frac{\sin^2(\varphi - \psi)}{\sin^2(\varphi + \psi)} - \frac{\text{tg}^2(\varphi - \psi)}{\text{tg}^2(\varphi + \psi)} \right] : \left[\frac{\sin^2(\varphi - \psi)}{\sin^2(\varphi + \psi)} + \frac{\text{tg}^2(\varphi - \psi)}{\text{tg}^2(\varphi + \psi)} \right]. \tag{5}$$

We shall consider n, the refraction coefficient of water, as constant and equal to 1.33. Then,

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$$\sin \psi = \sin \varphi : n = 0.75 \sin \varphi \qquad (6)$$

Formulas (3), (5), and (6) determine the dependence of s on φ and ξ. Consequently, these two angles must now be expressed through h, β, and ϑ. We make use of Figure 3a. We simultaneously derive the dependence on h, β, and ϑ of angle α, the angle of inclination of the normal to the surface of the water at the point reflecting the light of the sun to the point of the photograph that is under discussion (the dependence of α on h, β, and ϑ was first shown in work [2]). Angle α, similarly, depends on h, β, and ϑ, since at every point of the aerial photograph the sunlight can be mirrored only by a surface inclined in a certain way.
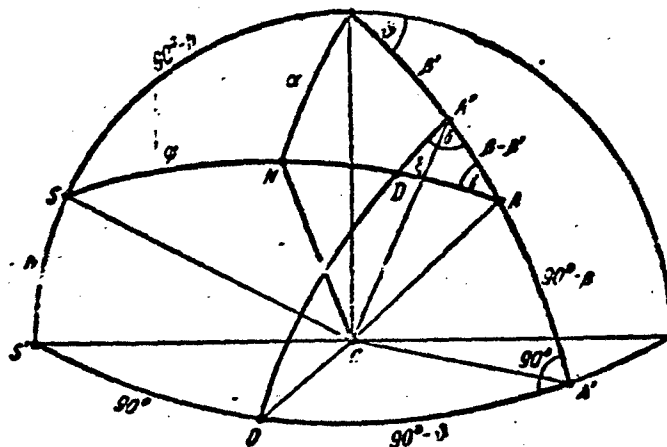
Fig. 3a
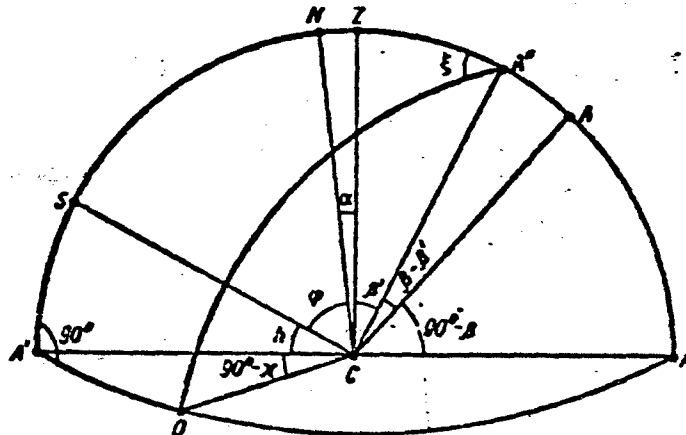
Fig. 3b

In Figure 3a, the directions that are of interest to us are passed through the center C of any sphere. All points designated in this Figure (except for point C) are traces of these directions on the sphere. CO is the "axis" of the polaroid, that is, its direction which, when made coincident with the plane of drop-reflection, will cause the polaroid to stop decreasing reflected light.

We shall assume that the polaroid is positioned horizontally and that its axis is perpendicular to the sun's vertical plane.

CZ is the vertical line; CS is the direction toward the sun; CS' is the projection of CS on the horizontal plane S'CO; CN is the normal to the surface of the water at the

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point that reflects the rays to point A of the photograph, having coordinates β and ϑ; CA is the projecting ray of point A, and CA' is its azimuth.

As stated earlier, β is read from optical axis AFA which is considered the vertical, and ϑ is read from the line on the photograph whose azimuth is opposite to that of the sun.

Therefore, $\angle$ SZA = $180° - \vartheta$ and $\smile$OA' = $90° - \vartheta$, while $\smile$ZA = β. It is also obvious that $\smile$NZ = α, while $\smile$SN = $\smile$NA = φ. Projecting ray CA on the edge of the polaroid will split. The ordinary ray will refract in its contact plane CAZ and within the thickness of the filter will assume direction CA''. Point A'' is located on the great circle ZA and $\smile$ZA'' = β' is connected with $\smile$ZA = β through equation

$$\sin \beta' = \sin \beta : n' = \beta : 1.521, \tag{7}$$

where $n' = 1.521$ is the refraction coefficient of the ordinary ray in the polaroid.

The light vector of the ordinary ray is perpendicular to plane OCA'' which passes through that ray and the axis of the polaroid. The light vector of the polarized portion of the projecting ray is perpendicular to plane CNA which passes through projecting ray CA and normal CN to the reflection surface.

Consequently, angle ξ equals the angle between planes OA''C and NAC, that is

$$\xi = \angle ADA''.$$

Let us examine spherical triangle ASZ; in it, $\smile$SA = 2φ, $\smile$SZ = $90° - h$, $\smile$ZA = β, $\angle$SZA = $\pi - \vartheta$. $\angle$SAZ, being an auxiliary angle, shall be designated as γ. From this triangle, we obtain

$$\cos 2\varphi = \sin h \cos \beta - \cos h \sin \beta \cos \vartheta, \tag{8}$$

$$\sin \gamma = \cos h \; \frac{\sin \vartheta}{\sin 2\varphi}. \tag{9}$$

Now, from triangle ZNA, we can determine α

$$\cos \alpha = \cos \beta \cos \varphi + \sin \beta \sin \varphi \cos \gamma. \tag{10}$$

Further, we introduce a second auxiliary angle δ, equal to angle OA''A' and we define it from triangle OA''A'. We obtain

$$\operatorname{ctg} \delta = \cos \beta' \operatorname{tg} \vartheta \tag{11}$$

Finally, from triangle DA''A we determine angle ξ with the aid of formula

$$\cos \xi = - \cos \gamma \cos \delta + \sin \gamma \sin \delta \cos (\beta - \beta'). \tag{12}$$

Formulas (3) and (5) through (12) will enable us to compute s and α from the known h, β, and ϑ.

We performed such calculations for all values of β and ϑ, with h equal to 15°, 25°, 35°, and 45°. The results of these calculations are given in Figure 4 in the form of isolines of the magnitudes $\alpha°$ and S%. The isolines of α are shown in dash lines, while isolines for s are given in dash-dotted lines.

The value of $\alpha°$ and S% along each isoline is noted at the point where the isoline reaches the frame of the illustration. To facilitate readout, dimensions of photographs 18 x 18 cm in size, with focal distances of 55 mm, 70 mm, 100 mm, 140 mm, and 200 mm are given. The photographs are obtained in different scales, since each point
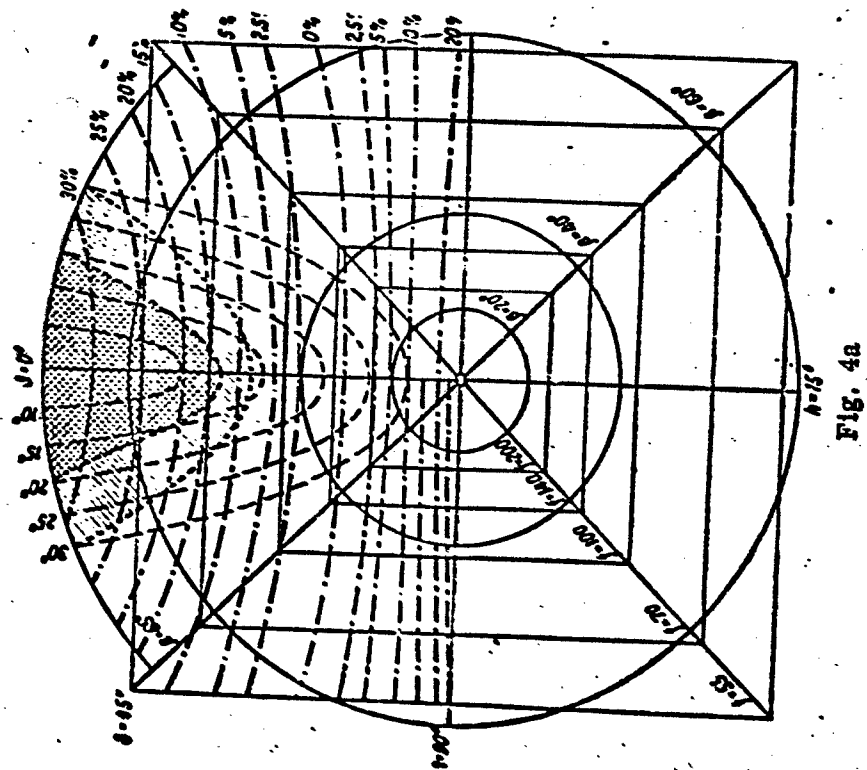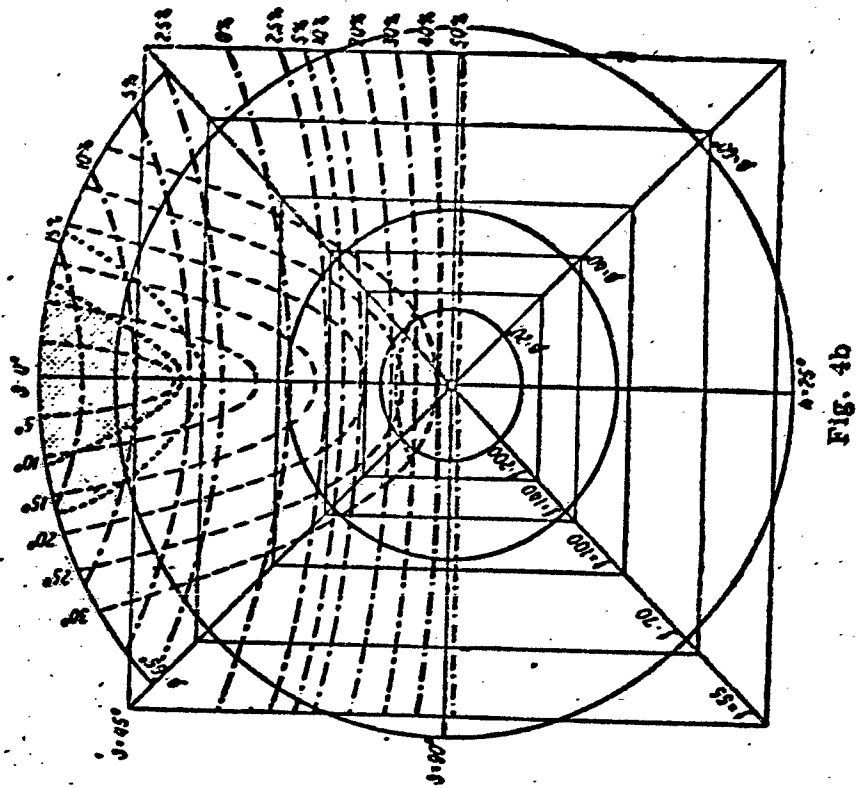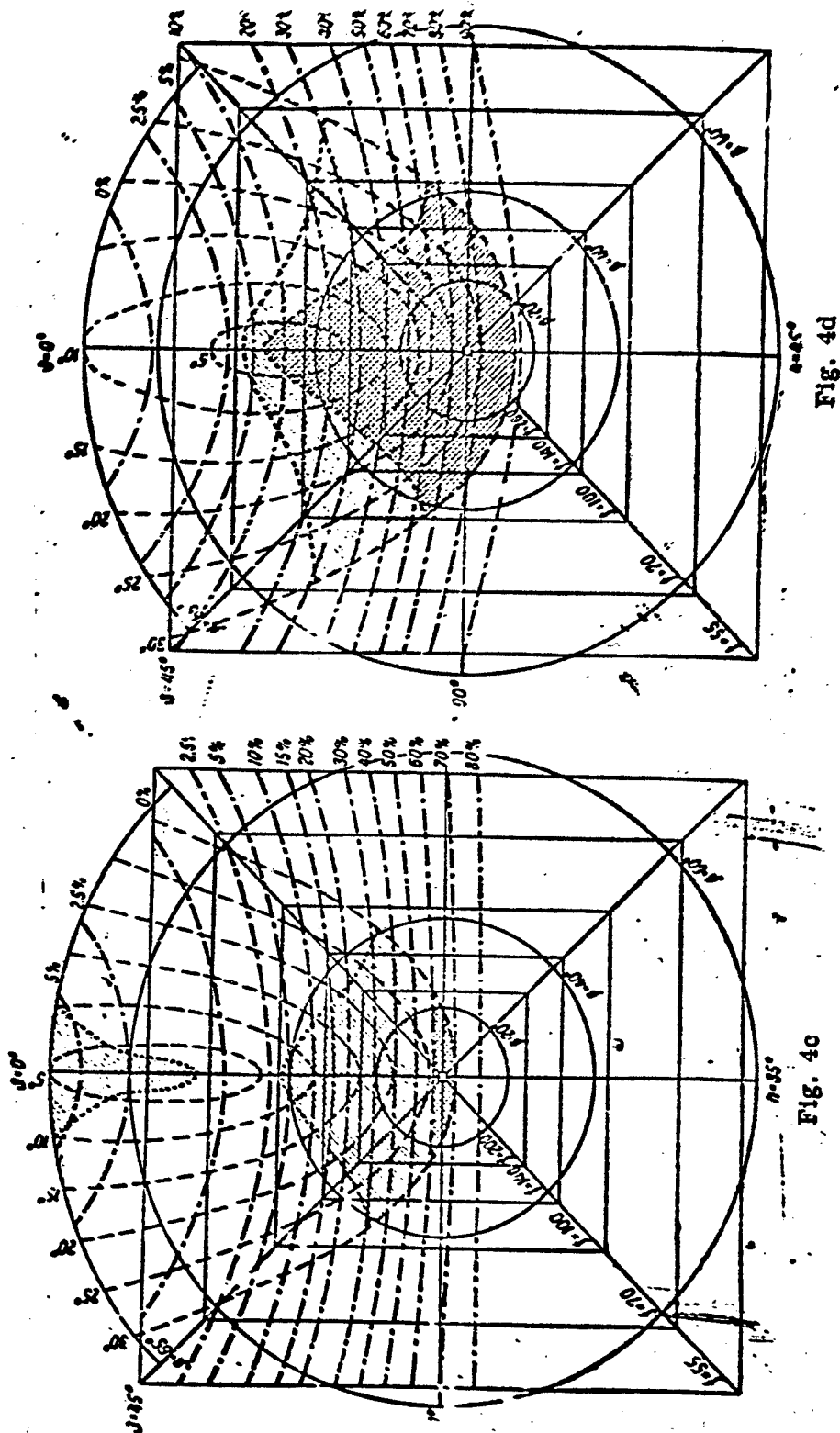
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Fig. 4b

Fig. 4a

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Fig. 4d

Fig. 4c

corresponds to a certain value of β, that is, in accordance with formula (4), a different distance r from the center for photographs having different f's. The photograph with f = 55 mm is represented on a scale of 1/2. The other photographs, on a scale of

$$M_r = \frac{55}{2f}.\qquad(13)$$

An evaluation of the results obtained is presented below.

Figure 4 was prepared on the premise that the axis of the polaroid is positioned strictly perpendicularly to the plane of the sun's vertical. In actual practice, a certain error is encountered. We shall determine the effect of this error on the diminution of the hot spot. As is evident from from Figure 4, the degree of diminution, within the broad change range of ϑ, is approximately the same as when $\vartheta = 0$. For this reason, to simplify matters, we shall consider that $\vartheta = 0$.

Figure 3b is a variation of Figure 3a. In it, $\vartheta = 0$, $\smile A'O = 90 - x \neq 90°$. x is the error in the positioning of the polaroid's axis. Formulas (8) and (12), when $\vartheta = 0$, are substantially simplified and assume the form

$$\varphi_0 = 0.5(90° \pm \beta - h)\qquad(14)$$

$$\alpha_0 = \pm 0.5(90° \mp \beta - h),\qquad(15)$$

where the upper signs are for points of the hot spot that are located on the azimuth that is opposite the sun's azimuth, between the center of the photograph and the center of the hot spot, while the lower signs for β are for points located beyond the center of the photograph (in the sun's vertical), and the sign "-" at α_0 is for points located at the edge of the photograph beyond the center of the hot spot.

In accordance with Figure 3b, angle ξ is determined from triangle A'A"O with the aid of the formula

$$\operatorname{ctg} \xi = \operatorname{tg} x \cos \beta'.\qquad(16)$$

Specifically, given the correct position of the polaroid, $\xi_0 = 90°$, that is, a correctly positioned polaroid absorbs the polarized light of that strip of the hot spot which lies in the sun's azimuth.

Formulas (14) and (16) enable us to calculate the effect of error resulting from the positioning of the polaroid x by coefficient s; it, for all practical purposes, does not depend on h and, therefore, the calculation can be made for any value of h. Given in Figure 5 are the results of such a calculation for h = 25°.

It can be seen from Figure 5 that the polaroid must be installed with a considerable degree of precision since, even when $x = 5°$, coefficient s increases substantially.

Isolines S (Figure 4), which show how the polaroid decreases the brightness of the sun spots throughout the total area, are of interest in themselves; they refute the widely held view that the polaroid can damp only a narrow portion of the hot spot, located perpendicularly to its axis. This view was based on the fact that when the polaroid was rotated 10-15°, the brightness of the polarized light passed by it increases severalfold. The latter, as can be seen from Figure 5, is true. The error results from identification of angle ϑ, that is, the angular width of the hot spot which, according to Figure 4, has little effect on coefficient s, with angle x, the error in positioning of the polaroid, which has a considerable effect.

It can be seen from Figure 4 that for aerovisual observations use of the polaroid is effective when it is necessary to survey, at one time, a considerable expanse of the surface of the water or even a large area of land which produces hot spots as a result of rain or dew. However, polaroids are of almost no help in the aerovisual interpretation
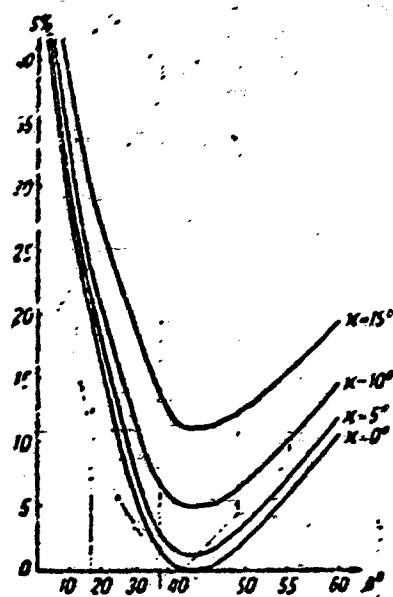
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of objects observed in a relatively small section in the direction of the nadir.

As to the question of the degree of diminution of the hot spot on the aerial film, knowledge of isoline S alone is not sufficient for its solution, since the density of the negative is not proportional to the brightness of the object.

2. Diminution of the density of the hot spot on aerial negatives. Limits of the applicability of polaroids. As is known, the interrelation between brightness (more precisely, exposure) of an object and the density of the photographic negative is determined by a characteristic curve whose form depends on the film selected and the method of development. Any characteristic curve has a range of normal exposition in which the increase in the density of the negative is proportional to the increase in the logarithm of the object's brightness and the range of under- or over-exposure, in which density becomes constant (that is, it is minimum or maximum for the given type of film), that is, it does not depend on the brightness of the object at all (for example, [6]).

Fig. 5

In the vicinity of the center of the hot spot zone, the sun is reflected from those sections of the surface which are close to the horizontals. These sections constitute a significant portion of the surface of the water and, as a result, the image of the center of the hot spot appears in the region of overexposures and even repeated diminutions in the brightness of the hot spot can fail to decrease its density. At the edge of the hot spot there appear sections of waves having maximum steepness. There are not too many such sections and the dimensions of each are not too great. As a result of this, a given grain of the film's emulsion is struck by light both from the glaring and the nonglaring portions of the water's surface, and the brightness of these sections averages out. Consequently, the bright spots at the edge are of varying brightness which gradually changes, as it moves away from the center of the hot spot, to the brightness of the wave on the side facing the sun, outside the hot spot. Therefore, the edge of the hot spot is represented by the straight-line portion of the characteristic curve and a diminution of it by 50% will reduce the density of its representation on the aerial photograph by 0.5-0.6, that is, quite significantly.

Thus, the degree of diminution of density of the hot spot at a given point on the photograph depends not only on coefficient s, but also on the brightness of the hot spot at that point. Brightness, in turn, depends on the shape of the wavy surface of the water, that is, on the hydrometeorological conditions of the survey. When the water is completely calm, the sun is reflected by it as if by a flat mirror, and as a result of this, the brightness of the hot spot is no less than two percent of the brightness of the sun's disc. The size of the hot spot on the aerial photograph in this case is of the order of one millimeter, however, it is not possible to reduce this density with the aid of a polaroid, since, to accomplish that, one would have to diminish the brightness tens of thousands of times. However, when there is even the slightest swell on the surface of the water, the area of the hot spot increases several thousandfold, and brightness diminishes correspondingly. In Figure 2b the hot spot is caused by a ripple superimposed over a swell. The hot spot does not cover a large area. If we were to determine α and S for its various points in accordance with the diagram given above (Figure 4b), we would find that, given α = 7, that is, in the region close to the center

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of the hot spot, the polaroid damped the hot spot when S = 2%, that is, when it diminished fifty-fold. Given α = 22, that is, at the edge of the given hot spot, the polaroid damped the hot spot when S = 15%. A hot spot that appear more washed out can be damped when values of S are considerably higher.

Therefore, with the given h, β, and ϑ (that is, with the given S and α), it can only be assumed that, on an average, the hot spot will be damped or diminished to some degree. This inevitably reduces the role played by polaroids in greatly washed out hot spots, and increases their importance for concentrated spots. Nevertheless, we consider that it is the latter that must help decide the question of the effectiveness of the use of polaroids for surveys of one or another kind. Average absorption and diminution values were determined by us after analysis of our experiment and comparison of hot spot images on aerial photographic film for differing hydrometeorological conditions; these are summarized in Table 1, prepared for h = 25°. As more experimental data are gathered, the information in Table 1 may change somewhat.

Table 1

α	0°	5°	10°	15°	20°	25°	30°	35°
Greatest S% at which hot spot is damped (h = 25°)...............	0	2	5	9	15	22	30	40
Greatest S% at which hot spot is significantly weakened (h = 25°)......	0	5	12	22	38	55	60	60

Given in Figure 4 are values of S and α. This made it possible to indicate on it (in less intense tone) that region in which, according to Table 1, the hot spot is not damped, but considerably weakened, and (in more intense tone) the region in which it remains. The hot spot is fully damped in the un-inked portion. When Table 1 data are extended to the case h ≠ 25°, a brightness change resulting from the change in angle of incidence φ is taken into account. Table 1 data and the inked portions of Figure 4 correspond to a polaroid with 5° error.

From the above it follows that use of the polaroid is effective in the struggle against hot spots but only when h ≤ 45° and for focal distances of the aerial camera of f < 140 mm (size of the photographs is 18 x 18 cm). A practically complete damping of the hot spot can be obtained only when h ≤ 25°, while in other cases the hot spot is reduced significantly, both in density and area. Use of polaroids is the more effective, the more wide-angled the objective of the aerial camera.

Hot spots that appear moderately washed out can be removed most effectively (α_{max} being of the order of 25-30°). A hot spot that is washed out more than that can rarely be wholly damped since it usually covers the entire portion of the frame, where s is large. It is difficult to weaken the center of a more concentrated hot spot, since its brightness is too great.

The photographs containing hot spots that have been included in this article were obtained with an aerial camera with f = 70 mm. Their h values were, respectively, 23° and 26°. Consequently, according to Figure 4, use of the polaroid with each of them must either leave a narrow strip of weakened hot spot at the edge of the frame, or must fully damp the hot spot. Leakage of diffused light must be fully corrected. This was confirmed experimentally (Figure 2). Completing our analysis of Figure 4, we note that the region of the spread of the spot on the photograph is generally limited by a certain isoline α (which depends on the degree to which the hot spot is washed out). However, when the swell of the waves is regular, the edge of the hot

spot recedes from isoline α and the hot spot becomes an elongated narrow strip (whose azimuth can differ by several tenths of a degree from that of the wave ray and the sun's azimuth).

3. Methodology of polaroid application. We shall describe the methodology we used in the above experiment and shall make note of improvements in it.

During manufacture, the axis of the light filter must be marked with graduated lines. If this is not done, they should be determined and marked. To accomplish this, the polaroid is placed in a rotating frame and fully polarized light is passed through it in a direction that is perpendicular to the plane of the polaroid. The polarized light is obtained by reflection, under the Brewster angle, of a bright directed pencil of light from the ends of flat parallel glass plates. When the polaroid has been rotated to a point of maximum damping of light, its axis is marked in the direction perpendicular to the drop-reflection plane of the light.

After the axis has been determined, the polaroid is mounted in the aerial camera. If the camera has external light filters (for example, the AFA-37), the polaroid is mounted on the frame of that filter. For this purpose, it is enclosed in a thin metal frame with handle and is attached to the filter. The handle will protrude through the side surface of the camera casing. When the handle is turned, the polaroid can be rotated with respect to the filter frame which is rigidly attached to the aerial camera case; thus its axis can be placed in the desired azimuth. The handle must come up against the graduation marks on the polaroid so that the direction from the optical axis of the camera will coincide with the axis of the polaroid. Rotation must be accomplished within a 180° arc. However, to facilitate operation during flight, it is more advantageous to provide 360° rotation. Adjacent to the end of the turning handle, a graduated scale is attached to the camera case in a manner such that the zero point corresponds to the parallelity of the polaroid's axis with the leading and back edge of the frame. In our experiment, the scale was marked off on a piece of adhesive tape mounted on the camera case.

When the aerial camera is not equipped with an external light filter, for example, the AFA-TE, a special holder must be attached to the cammera case so that a polaroid can be used with it. At present, the effectiveness of installing a special shutter in front of the camera's objective has been proven; this arrangement prevents parasitic light, which would not participate in constructing the image, from entering the objective [10a]. When such a shutter is provided, the polaroid and frame can be mounted on it (the shutter opening must be enlarged somewhat for this). When a special frame is made, it must be "adapted" to the camera and one must determine experimentally the size of the frame and support with handle, so that they will not cause a shadow on any part of the corners of the frame, but would also prevent parasitic light rays from entering (that is, would simultaneously serve as a shutter).

Exposure time during aerial surveys with polaroids must be increased by $1:0.5\,k$ times (see above), that is, threefold. This increase constitutes a basic shortcoming of polaroids.

Prior to the start of the survey, the polaroid must be adjusted by rotation of its handle to a point on the scale equal to angle A between the direction of the sun and the direction of the side edges of the frame. If we designate, respectively, the sun's azimuth, flight azimuth (i.e., the natural course, see [14]), and the angle of drift by A_Θ, A_n, and ω, we obtain

$$A = A_\Theta - A_n \div \omega \tag{17}$$

In formula (17) the drift angle must be taken into account if it is also taken into account in the flight, that is, when the aircraft is deployed at an angle minus ω, and the aerial camera—at an angle ω.

Angle A can be determined either from the sun-shade compass (STK) or it can

be calculated from the tables [10]. When an STK is available (even when it is not on [14]), the distance $A_\Theta - A_n$ must be measured directly on the image of the course leg, repeating these measurements and correcting adjustment of the polaroid as A_n changes or, if A_n remains unchanged, three to four times per hour. When no STK is available or when it is impossible or inconvenient to measure A_Θ directly in flight, adjustment of the polaroid becomes more complicated. In this case it is necessary, prior to flight, to write out from tables [10] the values of A_Θ for the section under survey for all possible values of survey time (at 15^m intervals) and to compute A in flight with the aid of these notes. If the natural flight angle $A'_n = A_n - \omega$ is given and is not expected to change in flight with respect to the position of the polaroid, magnitudes A can be computed in advance. However, this method is inconvenient in that it requires a definite determination of the drift angle which is sometimes difficult to determine during aerial photographic surveys of water.

Our experience indicates that it is possible to adjust the polaroid with an error rate not exceeding 5°. (It is difficult to achieve greater precision.) On the other hand, according to Figure 5, an error of 5° can be considered allowable. Taking into account both these factors, we consider 5° as the acceptable limit of error in the polaroid installation.

It should be noted that, when it is necessary to perform flights other than in a straight line (for example, along a shore line), the polaroid installation can be made only with respect to the median azimuth of the flight, which will result in a weakening of the polaroid's advantage. When azimuths of the flight change in excess of 10-15°, use of the polaroid is rendered ineffective.

Based on the methodology described, we performed two experimental flights, on August 7 and 8, 1958, at an altitude of the sun of 26° (August 7) and 22° (August 8), utilizing the AFA-37 aerial camera (f = 70 mm). The polaroid was mounted on the frame of the external light filter of the AFA-37 and was adjusted on the basis of magnitudes of A, computed prior to flight. Exposure was 1/50 sec when the polaroid was used, and 1/130 and 1/100 on comparison photographs taken without the polaroid. The film used was RF-3, diaphragm 6.3, internal light filter—ZhS-18, flight altitude—350 m, M = 1 : 5,000.

Photogrammetric review indicated that on August 7 the adjustment of the polaroid had an error of 5°, that on August 8—2°. Photos obtained on August 7 are shown in Figure 2. The survey on August 8 confirmed that, when h = 20°, the light is sufficient to perform surveys with the polaroid, but did not produce new data on the damping of hot spots, since during the flight the sea was calm and the hot spot did not reach the field of vision of the camera during the survey without polaroid.

The experiment described confirmed that it is possible to use polarization light filters to damp hot spots and internal light leaks in the objective of the aerial camera during aerial surveys of the sea.

The experiment further showed that use of the polaroid does not affect the sharpness and image contrast of the bottom contours and the surface of the water. (To check this premise, the axis of the polaroid was set both perpendicularly to the sun's azimuth as well as along the sun's azimuth.)

BIBLIOGRAPHY

1. Dubovskoy, B. V., and Perkis, L. A. Aerial Stereophotographic Surveys of Ocean Waves, Proceedings of the Government Institute for the Planning of Sea Ports and Wharf Installations, Vol. 3, 1956.

2. Zdanovich, V. G., and Sharikov, Yu. D. Certain tasks in the Study of Ocean Waves from Aerial Photographs, Anthology of Articles, Aeromethods Laboratory, USSR Academy of Sciences, 1954.

3. Landsberg, G. S. Optics, Moscow, Government Publishing House of Technical and Theoretical Literature, 1957.

4. Lyalikov, K. S., and Sharikov, Yu. D. Diffraction Analysis of Aerial Photographs of Wavy Sea Surfaces, Notes on Hydrography, No. 1, 1955.

5. Mangazeyev, V. Ya. Application of the Stereophotogrammetric Method in the Mapping of Underwater Relief, Proceedings of the Irkutsk Metal-Mining Institute, Vol. 15, 1958.

6. Mikhaylov, V. Ya. Aerial Photography and General Principles of Photography, Geodezizdat, 1959.

7. Potapenko, B. G. Stereophotogrammetric Mapping of Underwater Relief (Graduate Thesis), 1954.

8. Application of Aeromethods in Geological Explorations of the Bottom of the Sea, Brief Methodological Handbook edited by D. M Kudritskiy and V. V. Sharkov, Leningrad, Government Scientific-Technical Publishing House for Petroleum and Mining-Fuel Literature, Leningrad Section.

9. Ramm, N. S. and Khadzhetlashe, F. M. Certain Particularities of Stereophotogrammetric Processing of Aerial Photographs during Surveys through Two Media, Geographical Anthology, No. 7, 1955.

10. Tables for the Calculation of Natural Illumination and Visibility, Edited by V. V. Sharonov, Moscow-Leningrad, Publ. by USSR Academy of Sciences, 1945.

10a. N. A. Uspenskiy. Why Light Shadings Appear on Aerial Negatives, Geodeziya i i Kartografiya, No. 9, 1959.

11. Frish, S. E., and Timoreva, A. V. General Physics Course, Vol. 3, Moscow, Geotekhteorizdat, 1956.

12. Sharikov, Yu. D., Cherkasov, I. A., Mangazeyev, V. Ya. Stereophotographic Survey of Ocean Waves, Performed with the Aid of Two Aircraft, Notes on Hydrography, No. 1, 1958.

13. Sharikov, Yu. D., and Cherkasov, I. A. Use of Aerial Photographic Surveys in the Study of Surface Currents of the Ocean, Marine Anthology, No. 3, 1959.

14. Shershen', A. I. Aerial Photographic Surveys, Moscow, Geodezizdat, 1958.

15. Shuleykin, V. V. Physics of the Sea, Moscow, Publ. by USSR Academy of Sciences, 1953.

16. Yanutsh, D. A. On the Question of Utilization of the Photometric Properties of Aerial Photographs to Determine the Depth of Shallow Areas of the Sea, Journal of Scientific and Applied Photography and Cinematorgraphy, Vol. 2, Ed. 6, 1957.

17. Cruset, Jean. Photogrammetric measurement of the sea swell. Photogrammetria, Vol. IX, 1952-1953.

18. Wilbur Marks and F. Clau de Ronne. Aerial Stereophotography and ocean waves. Photogrammetric Engineering, Vol. XXI, No. 1, 1955.